**Forecasting climate-change induced effects on recreational and commercial fish populations in the Great Lakes**

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**Executive Summary:**

Great Lakes fishery managers and stakeholders have little information regarding how climate change could affect the management of recreationally and commercially important fisheries, which have been valued at more than $7 billion USD annually. Our research focused on how climate change could influence fish habitat (including water temperature, ice cover, and water levels), phytoplankton production that supports fish biomass, and ultimately the growth and consumption of many important recreational and commercial fish species.

First, we examined historical data on phytoplankton production and prey fish recruitment to determine the importance of climatic factors. When examining primary productivity between 1998 and 2008, we found no evidence that the spring phytoplankton bloom occurred earlier during warmer springs. Water temperature, however, was negatively related to annual primary production, which was contrary to our expectation and may be the result of increased grazing by zooplankton. Overall, the positive effects of spring total phosphorus and negative effects of dreissenid mussels overwhelmed the possible effects of climate. With respect to prey fish recruitment, we explored the effects of multiple biotic and climatic factors regulating three key species using time series spanning at least 40 years. For alewife in Lake Michigan, recruitment was most strongly influenced by salmon predation, while spring and summer water temperatures also were positively related to strong year-classes. Lake Huron alewife recruitment variation was not well explained by any factor we examined, including water temperature and water level. Bloater recruitment in lakes Michigan and Huron was most strongly correlated with the sex ratio of the population; winter and spring water temperatures provided no explanatory power. Finally, rainbow smelt recruitment was evaluated in Lake Michigan and the primary finding was that the stock/recruitment relationship varied over the time series. Several environmental variables (ice cover, precipitation, and water level) did not explain significant variation.

Second, we generated downscaled climate forecasts for the Great Lakes basin between 2043 and 2070 and then predicted the effects of future water temperature on fish growth and consumption. We updated a Coupled Hydrosphere Atmosphere Research Model that predicted vertical water temperature profiles, ice cover, and precipitation within 40-km grids and lake levels for Lakes Michigan and Huron. This model was forced by the Coupled General Circulation Model version 3 of the Canadian Centre for Climate Modelling and Analysis, and run under the A2 greenhouse-gas emission scenario. The model predicted 2-3 °C increases in temperature throughout the water column in summer through autumn and a longer period of vertical water stratification. Other predictions included more snowfall within lake-effect regions of the Great Lakes, more rainfall in summer (but without a strong spatial pattern), and

less ice cover in lakes Michigan and Huron. Lastly, we predicted the growth and consumption of lake trout, Chinook salmon, lake whitefish, yellow perch, and steelhead trout in 2043-2070 in lakes Huron and Michigan. We assumed that fish would occupy their physiological optimal temperature if it was available and considered different scenarios of prey densities (lower than present, present, higher than present). Under future climate predictions, all fish species will have more days when their optimal temperature is available. Predictions for specific fish species varied owing to the seasonal dynamics of the energy density of their prey and their basal metabolic costs. For all fish species, however, the densities of their prey played a key role in determining the future growth and consumption.

In summary, several aspects of future climate could affect fish habitat and ultimately, fish production, in the Great Lakes. At the same time, our research revealed that other factors, such as densities of invasive mussels or spring total phosphorus concentrations for primary production, or densities of prey or predator biomass for fishes, have a more important effect on biological responses. Hence, future research should consider forecasted climate changes within a broader ecosystem perspective to best predict how fisheries will respond to a changing environment.